CLAIMS

1. (Currently amended) A hardware apparatus for analyzing a sound signal, comprising:

an ear model for deriving, for a number of inner hair cells, an estimate for a time-varying concentration of a transmitter substance inside a cleft between an inner hair cell and an associated auditory nerve from the sound signal, so that an estimated inner hair cell cleft contents map over frequency and over time is obtained, wherein the inner hair cells comprising lower order inner hair cells indicating lower frequencies and higher order inner hair cells indicating higher frequencies; and

a pitch analyzer for analyzing the cleft contents map to obtain a pitch line over time, the pitch line indicating a pitch of the sound signal for respective time instants, wherein the pitch line varies in time over higher frequencies and lower frequencies as determined by the pitch analyzer; ~~.~~

wherein the pitch analyzer further comprises a vibration period detector, the vibration period detector being operative for calculating a summary auto correlation function for each time period of a number of adjacent time periods using the estimates for the transmitter concentrations of the number of inner hair cells, and

wherein the vibration period detector is further operative, for each inner hair cell, to calculate at least one period value describing a time distance between two adjacent maxima in one estimate, and to enter a resulting period value into a summary auto correlation function histogram.

2. (Previously presented) The hardware apparatus in accordance with claim 1, further comprising a rhythm analyzer for analyzing estimates for selected inner hair cells, the inner hair cells being selected in accordance with the pitch line, so that segmentation instants are obtained, wherein a segmentation instant indicates an end of a preceding note or a start of a succeeding note.

3. (Previously presented) The hardware apparatus in accordance with claim 1, in which the ear model comprises:

a mechanical ear model for modeling an auditory mechanical sound processing up to the inner ear (cochlea) to obtain estimates for representations of mechanical vibrations of the basilar membrane and lymphatic fluids; and

an inner hair cell model for transforming the estimates for representations of mechanical vibrations into the estimates for the transmitter concentrations at the inner hair cells.

4. (Previously presented) The hardware apparatus in accordance with claim 1, in which the ear model is operative to calculate a transmitter concentration for at least 100 inner hair cells,

wherein each inner hair cell is associated with a specified area of a modeled basilar membrane, and wherein each inner hair cell has associated therewith a different specified area of the modeled basilar membrane.

5. (Cancelled)

6. (Currently amended) The hardware apparatus in accordance with claim 1~~5~~, in which the pitch analyzer is operative

to retrieve a maximum value from each histogram of the time sequence of histograms, the maximum value representing a pitch in the time period so that pitch line points are obtained.

7. (Previously presented) The hardware apparatus in accordance with claim 6, in which the pitch analyzer is further operative to build pitch line subtrajectories by combining pitch line points being close in time with respect to a time threshold and being close in frequency with respect to a frequency threshold.

8. (Previously presented) The hardware apparatus in accordance with claim 7, in which the pitch line analyzer is further operative to fuse pitch line subtrajectories with a minimum length and to discard any subtrajectories not fulfilling a criterion related to a minimum length and amplitude.

9. (Currently amended) The hardware apparatus in accordance with claim 252, in which the rhythm analyzer comprises a searcher for searching a dominant estimate for a transmitter concentration in a specified time period and comprising a dominant frequency determined by the pitch line so that, for adjacent time periods, corresponding dominant estimates for different inner hair cells are obtained, wherein the searcher is operative to acknowledge a dominant estimate, when the dominant estimate is above a threshold.

10. (Previously presented) The hardware apparatus in accordance with claim 9, in which the threshold is an amplitude of an estimate comprising the second largest amplitude so that the dominant estimate comprises the largest amplitude in a specified time period.

11. (Currently amended) The hardware apparatus in accordance with claim 252, in which the rhythm analyzer is

operative to build an onset map by calculating an onset value for a dominant estimate for a specified time period, the onset map including a sequence of onset values.

12. (Previously presented) The hardware apparatus in accordance with claim 11, in which the rhythm analyzer is operative to calculate an onset value such that an onset value is higher, when an onset comprises a stronger onset rise, compared to another onset comprising a weaker onset rise.

13. (Previously presented) The hardware apparatus in accordance with claim 11, in which the rhythm analyzer is operative to calculate an onset value such that the onset value is higher, when a starting level before an onset is lower compared to another onset comprising a higher starting level.

14. (Currently amended) The hardware apparatus in accordance with claim 252, in which the rhythm analyzer is operative to use an estimate for an inner hair cell representing a fundamental vibration or using an estimate for an inner hair cell representing at least one higher partial vibration.

15. (Currently amended) The hardware apparatus in accordance with claim 252, in which the rhythm analyzer is operative to build an onset histogram by combining onset values of estimates for an inner hair cell representing the fundamental vibration, and onset values of an estimate for an inner hair cell representing at least one higher partial vibration, which comprises a time distance smaller than a specified time distance threshold.

16. (Previously presented) The hardware apparatus in accordance with claim 11, in which the rhythm analyzer

is operative to extract maxima from the onset histogram, wherein a time value associated with a maximum indicates a segmentation instant.

17. (Previously presented) The hardware apparatus in accordance with claim 1, further comprising a timbre recognition module, the timbre recognition module being operative for:

constructing a feature vector;

feeding the feature vector into a pattern recognition device; and

obtaining a result indicating a probability that at least a portion of the sound signal has been produced by a sound source from a number of different specified sound sources.

18. (Currently amended) The hardware apparatus in accordance with claim 2817, in which the pattern recognition device is a neural network.

19. (Currently amended) The hardware apparatus in accordance with claim 2817, in which the feature vector comprises one or more selected members from a feature group including onset time of a fundamental vibration or a higher order partial vibration, a frequency of a fundamental vibration or a higher order partial vibration, an amplitude of a fundamental vibration or a higher order partial vibration, a number of an estimate for the transmitter concentration using the highest peak for the fundamental vibration or a higher order partial vibration, or a number of an estimate for the transmitter concentration being in resonance for a fundamental vibration or a higher order partial vibration.

20. (Currently amended) The hardware apparatus in accordance with claim ~~2~~25, further comprising a transcription module, the transcription module being operative for using the pitch line segmented at segmentation instants to output a note description or a MIDI description.

21. (Currently amended) A method of analyzing a sound signal, comprising:

deriving, for a number of inner hair cells, an estimate for a time-varying concentration of a transmitter substance inside a cleft between an inner hair cell and an associated auditory nerve from the sound signal, so that an estimated inner hair cell cleft contents map over frequency and over time is obtained, wherein the inner hair cells comprising lower order inner hair cells indicating lower frequencies and higher order inner hair cells indicating higher frequencies; and

analyzing the cleft contents map to obtain a pitch line over time, a pitch line indicating a pitch of the sound signal for respective time instants, wherein the pitch line varies in time over higher frequencies and lower frequencies as determined by analyzing the cleft contents map~~$_T$~~; and

calculating a summary auto correlation function for each time period of a number of adjacent time periods using the estimates for the transmitter concentrations of the number of inner hair cells,

wherein, for each inner hair cell, at least one period value describing a time distance between two adjacent maxima in one estimate is calculated, and wherein a resulting period value is entered into a summary auto correlation function histogram.

wherein the method of analyzing is implemented in hardware in the form of a state machine or in software, which is executed by a programmable processor for performing the method of analyzing.

22. (Withdrawn) Computer program having instructions being operative for performing a method of analyzing a sound signal when the program runs on a computer, the method of analyzing a sound signal comprising the following steps:

deriving, for a number of inner hair cells, an estimate for a time-varying concentration of a transmitter substance inside a cleft between an inner hair cell and an associated auditory nerve from the sound signal, so that an estimated inner hair cell cleft contents map over time is obtained; and

analyzing the cleft contents map to obtain a pitch line over time, a pitch line indicating a pitch of the sound signal for respective time instants.

23. (Previously presented) The hardware apparatus of claim 1,

wherein the pitch line over time is used for one or more members of the group comprising: performing a transcription, performing a sound source recognition, performing a music recognition, performing a query by humming process, displaying the pitch line over time, extracting auditory streams, identifying performing singers, and performing an instrument recognition.

24. (Previously presented) The method of claim 21,

wherein the pitch line over time is used for one or more members of the group comprising: performing a transcription, performing a sound source recognition, performing a music recognition, performing a query by humming process, displaying the pitch line over time, extracting auditory streams, identifying performing singers, and performing an instrument recognition.

25. (New) A hardware apparatus for analyzing a sound signal, comprising:

an ear model for deriving, for a number of inner hair cells, an estimate for a time-varying concentration of a transmitter substance inside a cleft between an inner hair cell and an associated auditory nerve from the sound signal, so that an estimated inner hair cell cleft contents map over frequency and over time is obtained, wherein the inner hair cells comprising lower order inner hair cells indicating lower frequencies and higher order inner hair cells indicating higher frequencies; and

a pitch analyzer for analyzing the cleft contents map to obtain a pitch line over time, the pitch line indicating a pitch of the sound signal for respective time instants, wherein the pitch line varies in time over higher frequencies and lower frequencies as determined by the pitch analyzer;

a rhythm analyzer for analyzing estimates of the time-varying concentration of the transmitter substance for selected inner hair cells, the inner hair cells being selected in accordance with the pitch line, so that segmentation instants are obtained, wherein a segmentation instant indicates an end of a preceding note or a start of a succeeding note;

wherein the rhythm analyzer is configured to select an inner hair cell which vibrates with a pitch frequency or a partial frequency.

26. (New) The hardware apparatus according to claim 25, wherein the rhythm analyzer is configured to make use of certain transmitter concentration envelopes identified by the pitch line to perform segmentation of the pitch line.

27. (New) A method of analyzing a sound signal, comprising:

deriving, for a number of inner hair cells, an estimate for a time-varying concentration of a transmitter substance inside a cleft between an inner hair cell and an associated auditory nerve from the sound signal, so that an estimated inner hair cell cleft contents map over frequency and over time is obtained, wherein the inner hair cells comprising lower order inner hair cells indicating lower frequencies and higher order inner hair cells indicating higher frequencies; and

analyzing the cleft contents map to obtain a pitch line over time, a pitch line indicating a pitch of the sound signal for respective time instants, wherein the pitch line varies in time over higher frequencies and lower frequencies as determined by analyzing the cleft contents map; and

selecting inner hair cells in accordance with the pitch line,

wherein an inner hair cell is selected which vibrates with a pitch frequency or in partial frequency;

analyzing estimates of the time-varying concentration of the transmitter substance for the selected inner hair

cells, so that segmentation instants are obtained, wherein a segmentation instant indicates an end of a preceding note or a start of a succeeding note; and

wherein the method of analyzing is implemented in hardware in the form of a state machine or in software, which is executed by a programmable processor for performing the method of analyzing.

28. (New) A hardware apparatus for analyzing a sound signal, comprising:

an ear model for deriving, for a number of inner hair cells, an estimate for a time-varying concentration of a transmitter substance inside a cleft between an inner hair cell and an associated auditory nerve from the sound signal, so that an estimated inner hair cell cleft contents map over frequency and over time is obtained, wherein the inner hair cells comprising lower order inner hair cells indicating lower frequencies and higher order inner hair cells indicating higher frequencies; and

a pitch analyzer for analyzing the cleft contents map to obtain a pitch line over time, the pitch line indicating a pitch of the sound signal for respective time instants, wherein the pitch line varies in time over higher frequencies and lower frequencies as determined by the pitch analyzer;

a timbre recognition module, the timbre module being operative for:

constructing a feature vector;

feeding the feature vector into a pattern recognition device; and

obtaining a result indicating a probability that at least a portion of the sound signal has been produced by a sound source from a number of different specified sound sources;

wherein the timbre recognition module is configured to construct the feature vector such that the feature vector comprises feature values describing relations of the frequencies of higher partials and the fundamental.

29. (New) The hardware apparatus according to claim 28, wherein the timbre recognition module is configured to construct the feature vector such that the feature vector comprises feature values describing differences between times at which cleft content envelopes of partials and a cleft content envelope of the fundamental reach maxima.

30. (New) A method of analyzing a sound signal, comprising:

deriving, for a number of inner hair cells, an estimate for a time-varying concentration of a transmitter substance inside a cleft between an inner hair cell and an associated auditory nerve from the sound signal, so that an estimated inner hair cell cleft contents map over frequency and over time is obtained, wherein the inner hair cells comprising lower order inner hair cells indicating lower frequencies and higher order inner hair cells indicating higher frequencies; and

analyzing the cleft contents map to obtain a pitch line over time, a pitch line indicating a pitch of the sound signal for respective time instants, wherein the pitch line varies in time over higher frequencies and lower frequencies as determined by analyzing the cleft contents map; and

performing a timbre recognition, wherein performing a timbre recognition comprises:

constructing a feature vector, such that the feature vector comprises feature values describing relations of frequencies of higher partials and the fundamental, and

performing a pattern recognition on the basis of the feature vector, to obtain a result indicating a probability that at least a portion of the sound signal has been produced by a sound source from a number of different specified sound sources;

wherein the method of analyzing is implemented in hardware in the form of a state machine or in software, which is executed by a programmable processor for performing the method of analyzing.